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**E21B 43/08 43/10 43/14**

(52) UK CL (Edition T)

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**GB 2343691 A**

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**EP 0360597 A**

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**US 5901789 A**

(58) Field of Search

**UK CL (Edition T) E1F FJB FJF FLA FLW FMU**

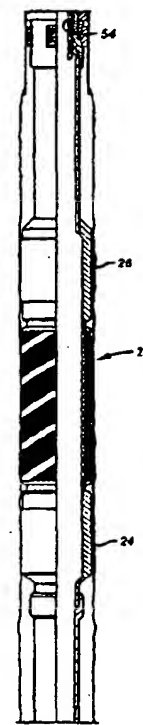
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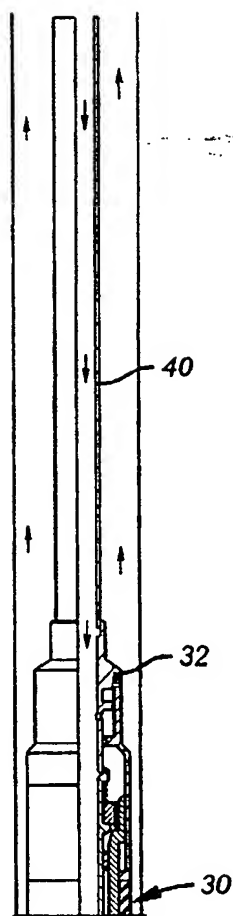
(54) Abstract Title

**A method for well completion using an expandable isolation system**

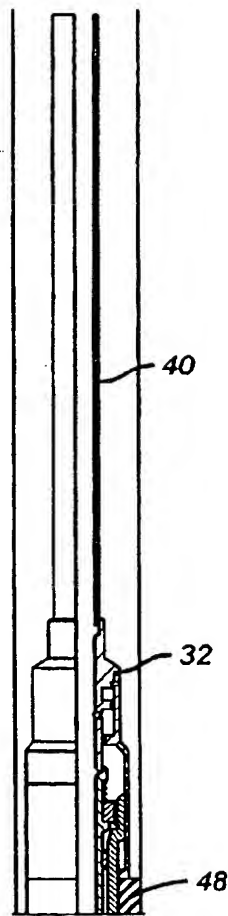
(57) A well completion method for isolating at least one zone which comprises running into the wellbore a string with isolators 24, 26 in conjunction with a screen 28 which allows flow from the surrounding formation into the string and expanding the isolators and the screen in the wellbore. The isolators are tubular with a sleeve of an elastomeric sealing material. The screen is made of a weave in one or more layers. The completion assembly includes an inflatable expansion assembly which provides a limited expansion force and/or diameter. A plurality of zones can be isolated on a single trip.



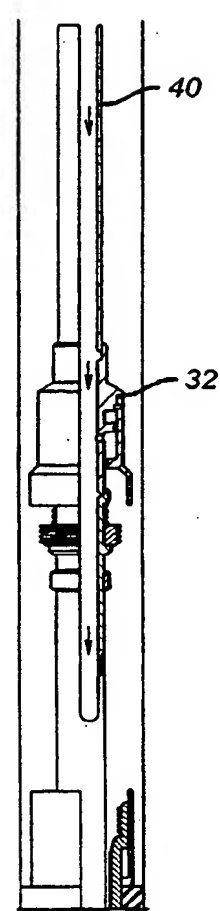
**FIG. 5b**



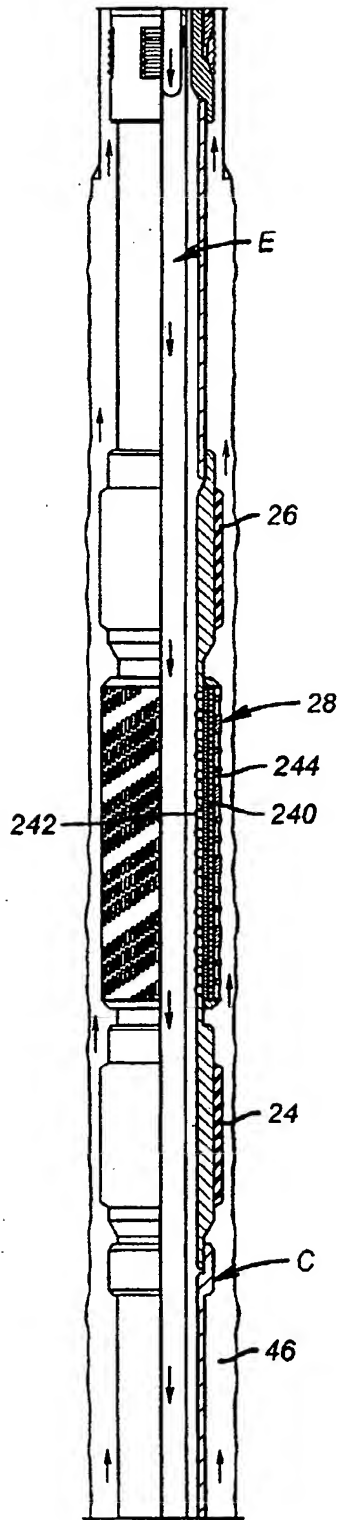
**FIG. 1a**



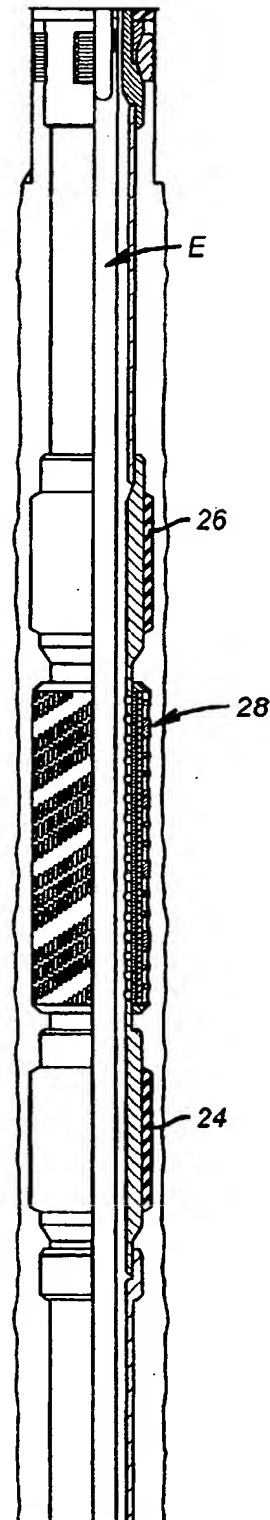
**FIG. 2a**



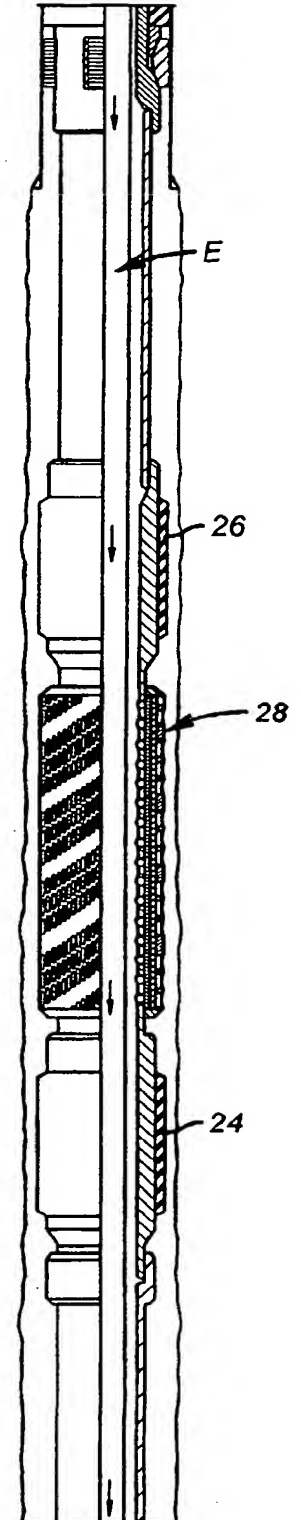
**FIG. 3a**



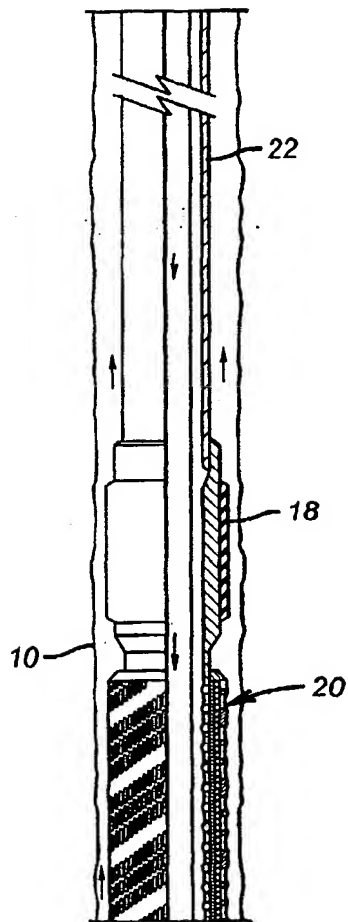
**FIG. 1b**



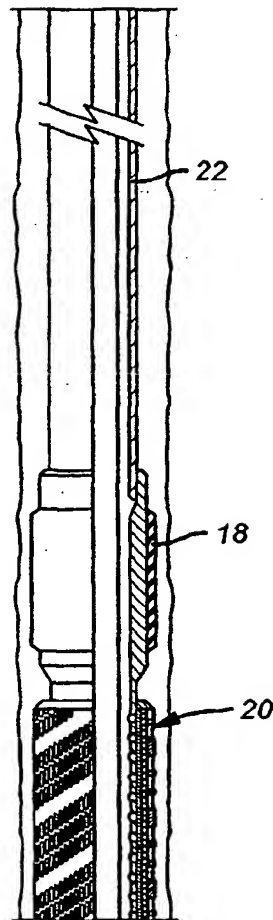
**FIG. 2b**



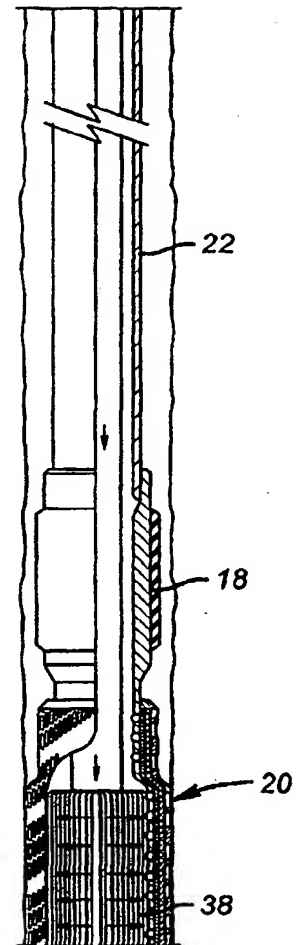
**FIG. 3b**



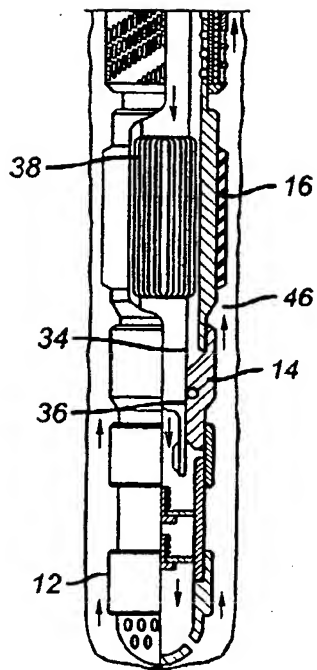
**FIG. 1c**



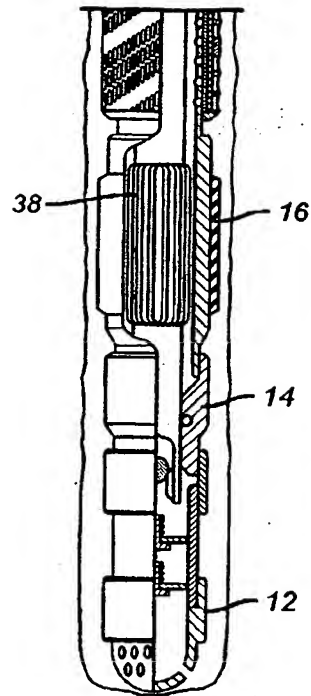
**FIG. 2c**



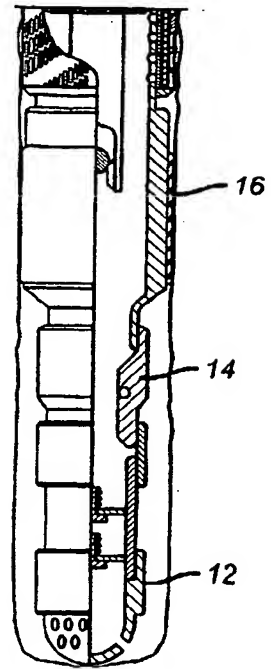
**FIG. 3c**



**FIG. 1d**



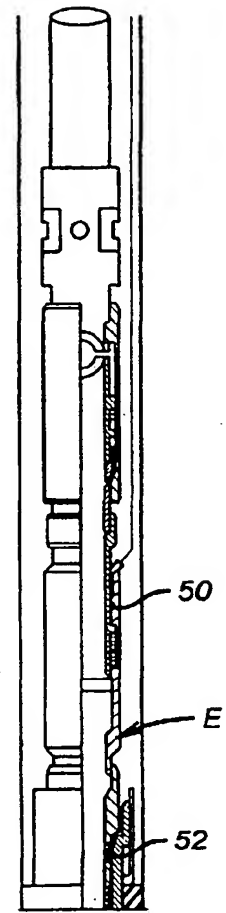
**FIG. 2d**



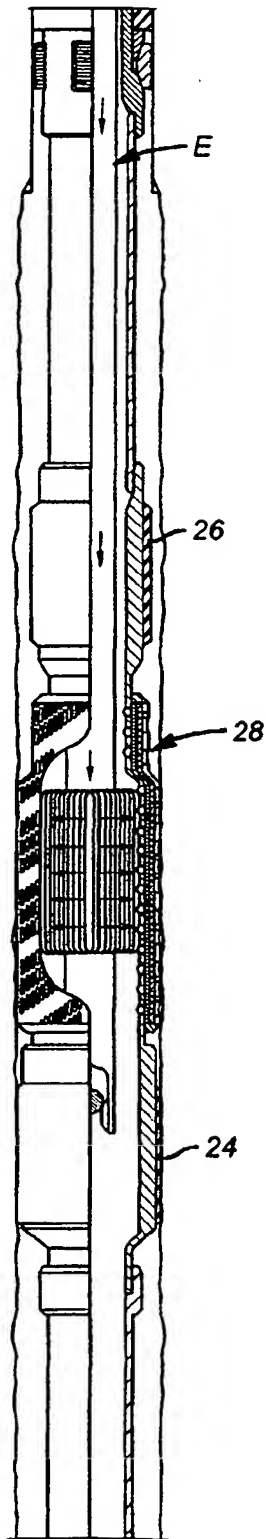
**FIG. 3d**



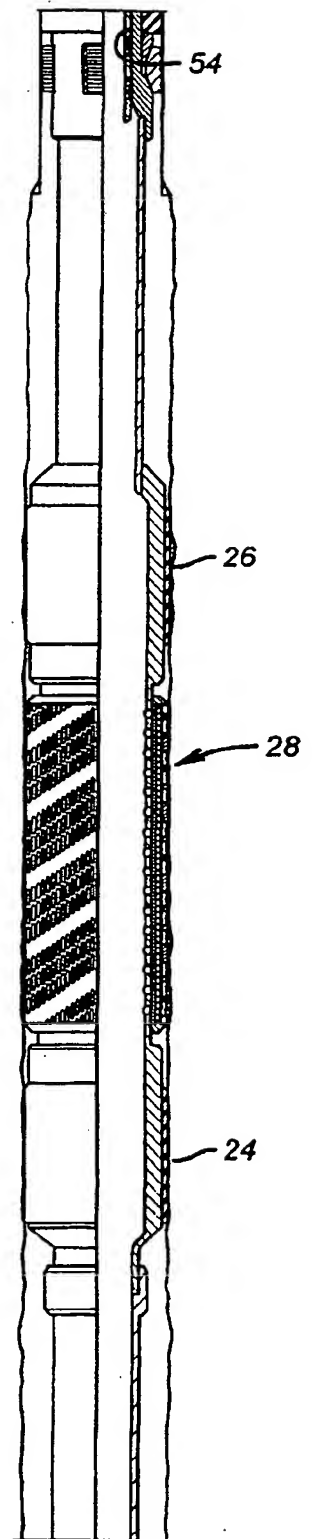
**FIG. 4a**



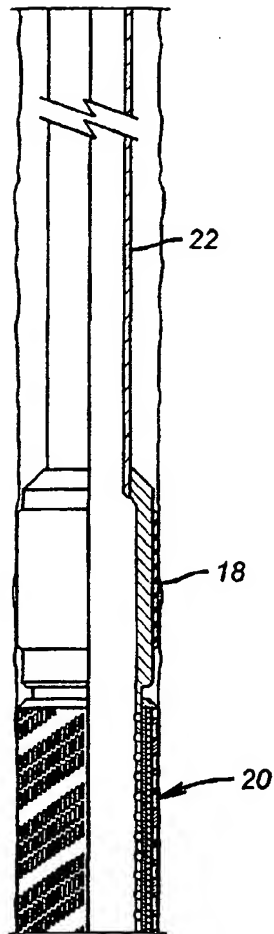
**FIG. 5a**



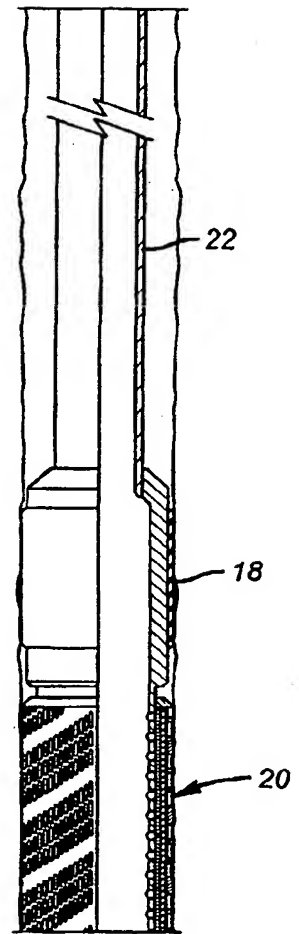
**FIG. 4b**



**FIG. 5b**

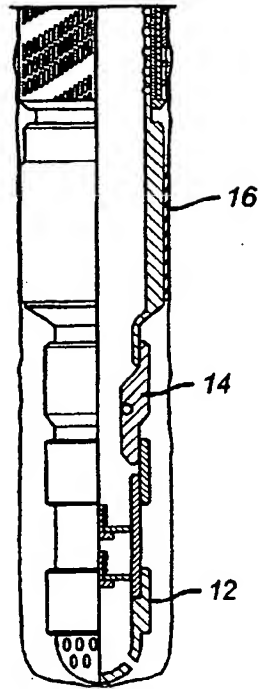


**FIG. 4c**

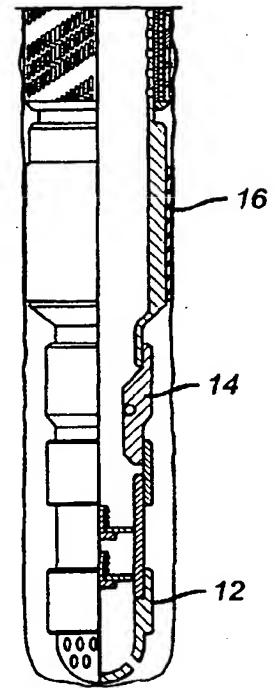


**FIG. 5c**





**FIG. 4d**



**FIG. 5d**

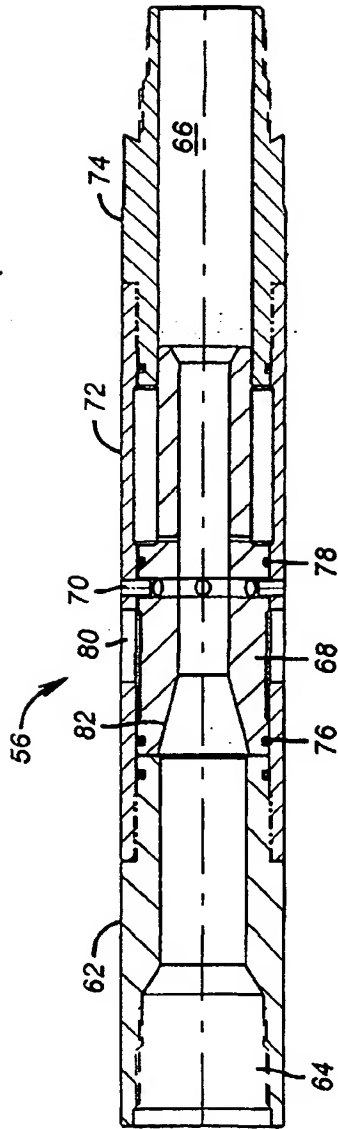


FIG. 6

9/20

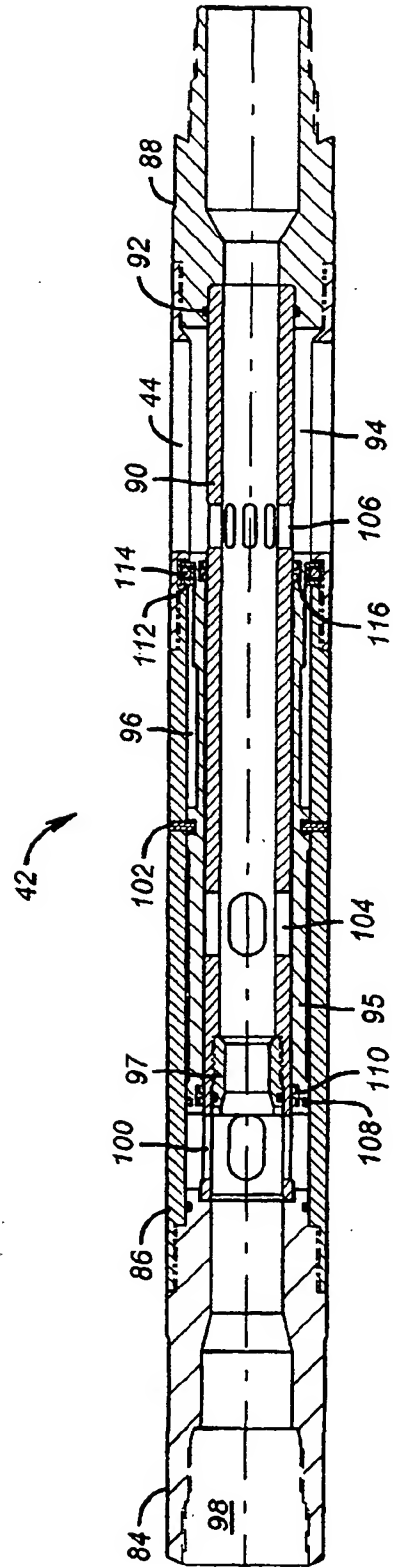
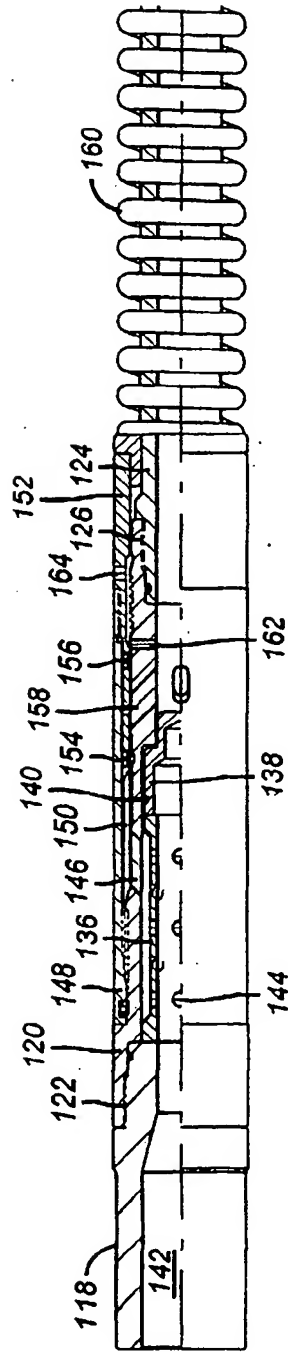
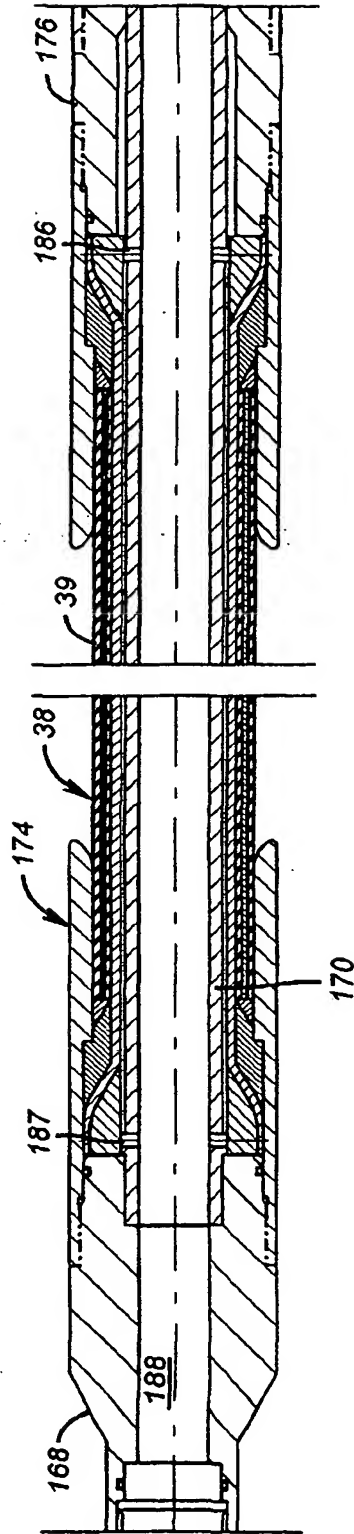


FIG. 7



**FIG. 8a**



**FIG. 9a**

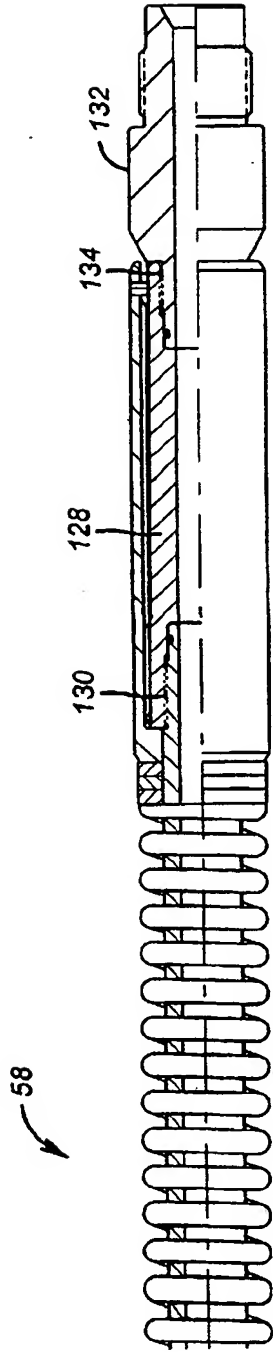


FIG. 8b

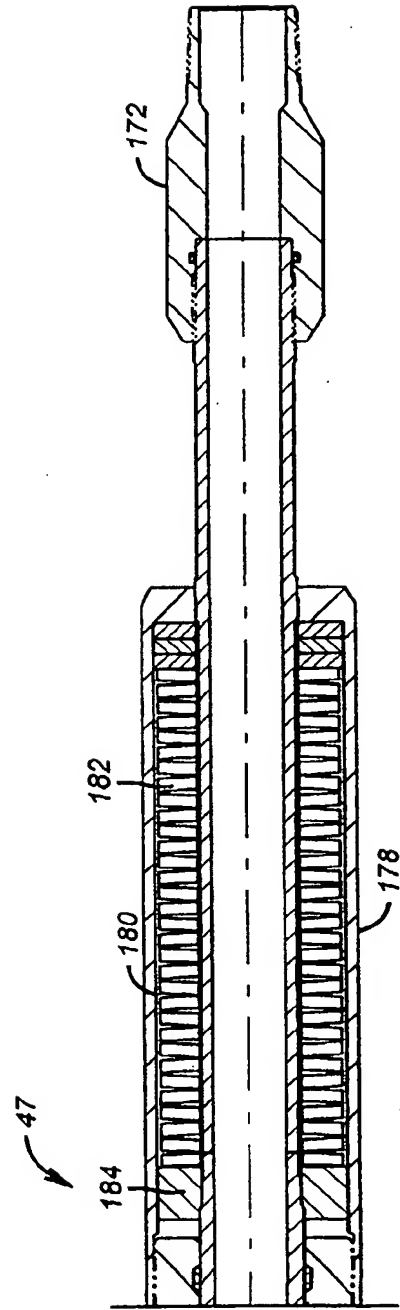
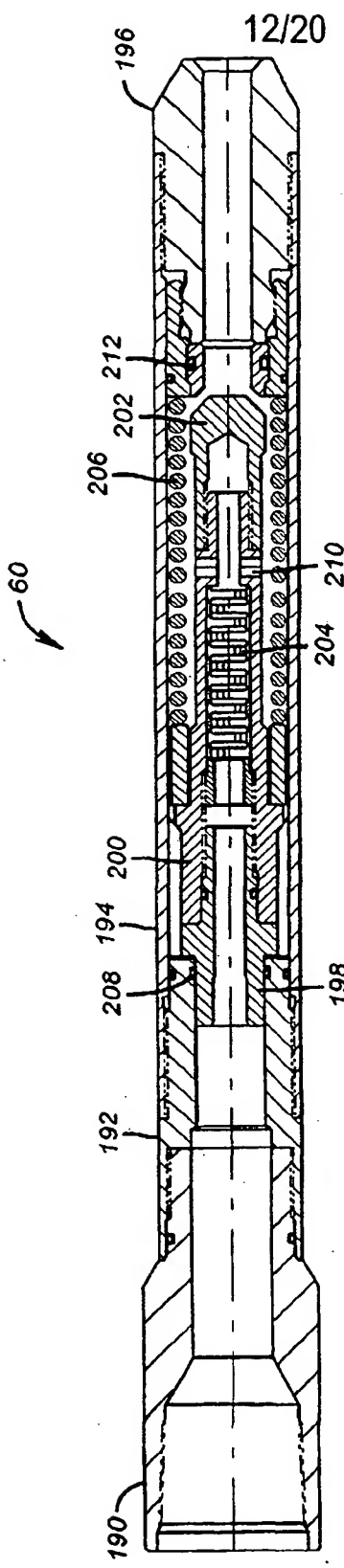


FIG. 9b

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12/20

FIG. 10

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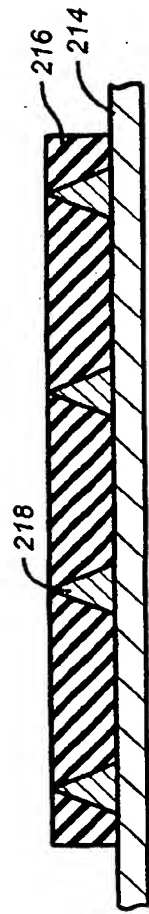


FIG. 11

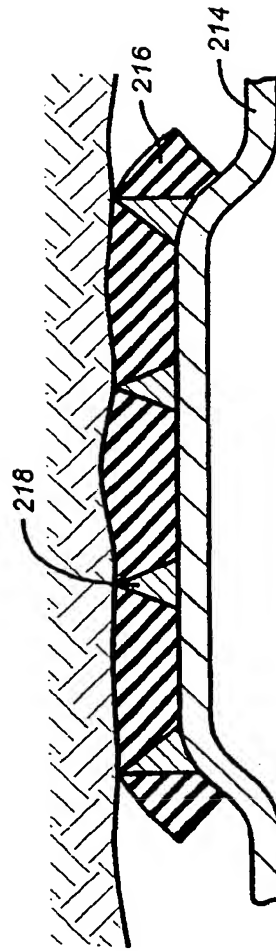


FIG. 12

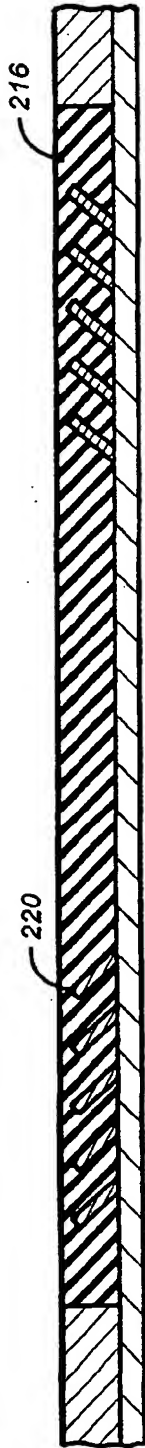


FIG. 13

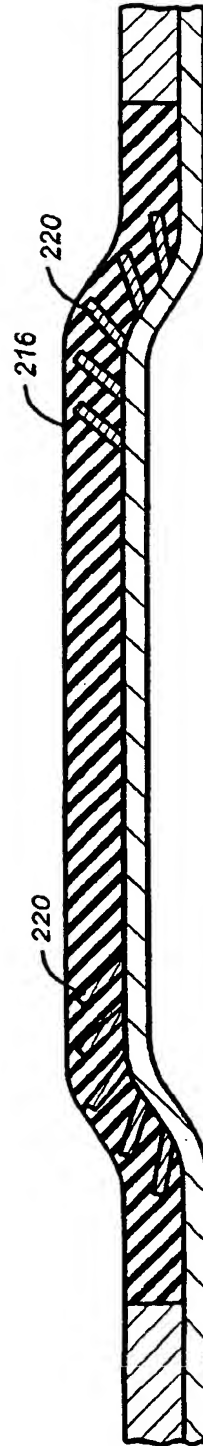


FIG. 14

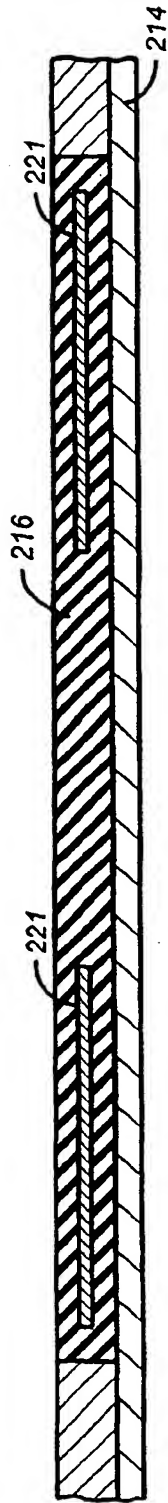


FIG. 15

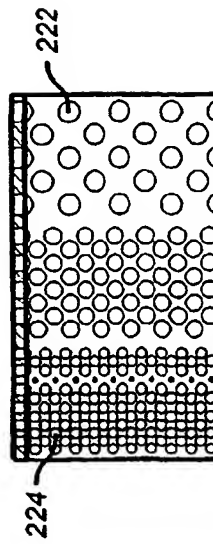


FIG. 16

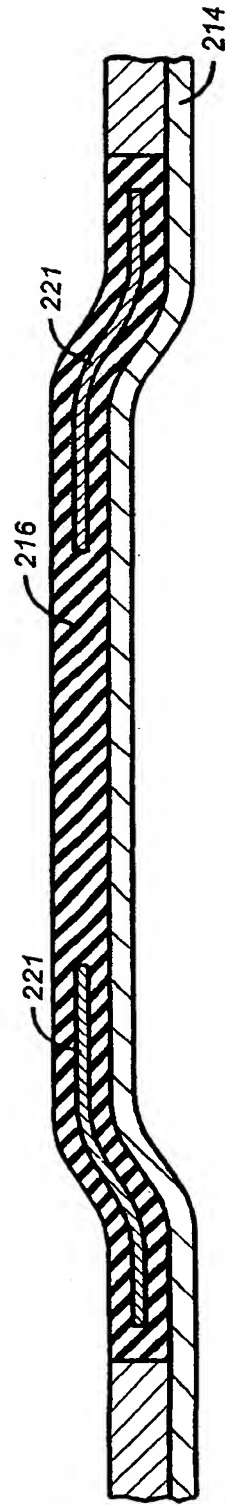


FIG. 17



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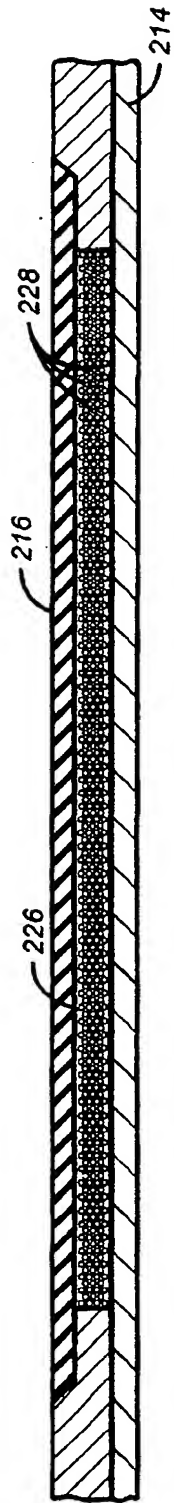


FIG. 18

16/20

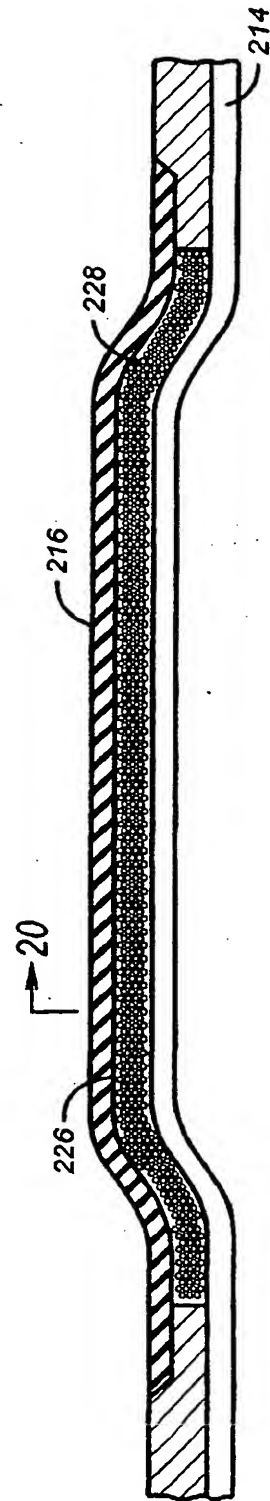
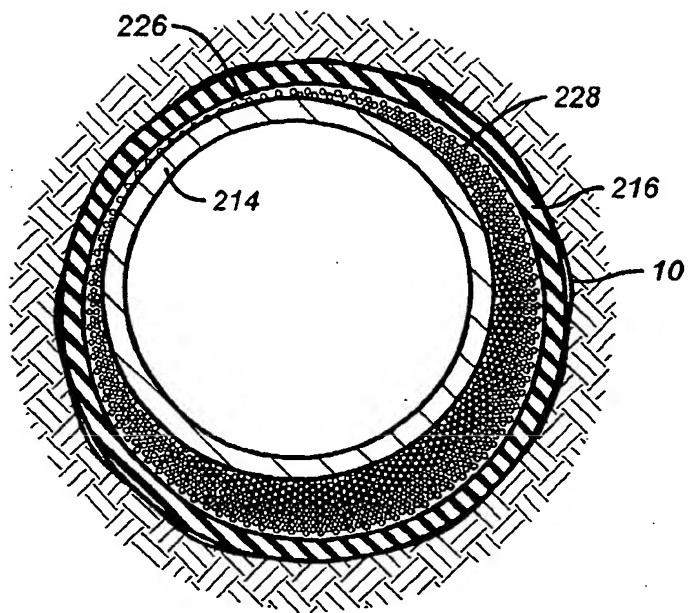
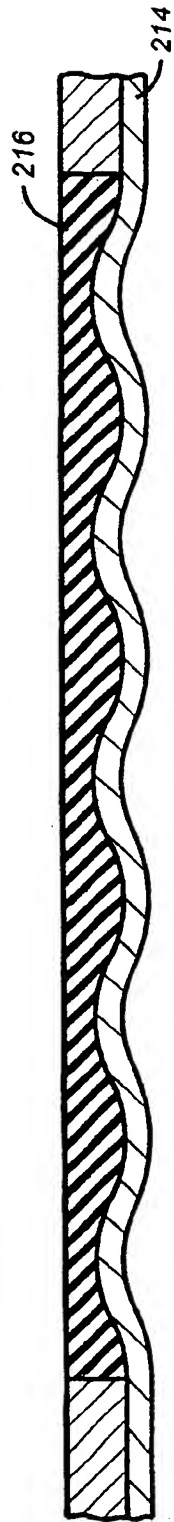


FIG. 19

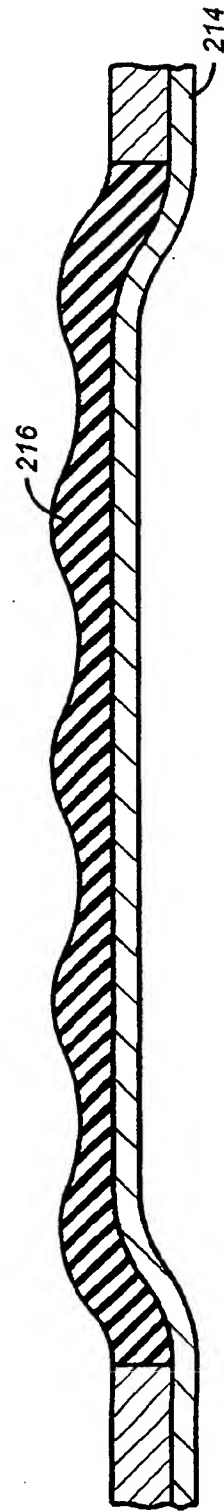
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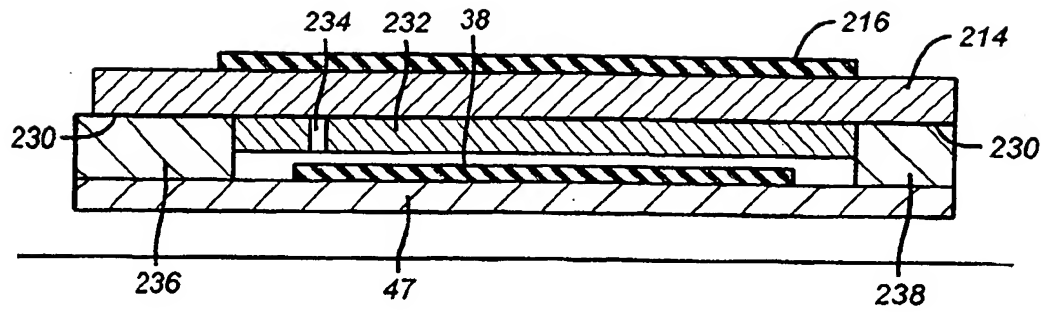
**FIG. 20**



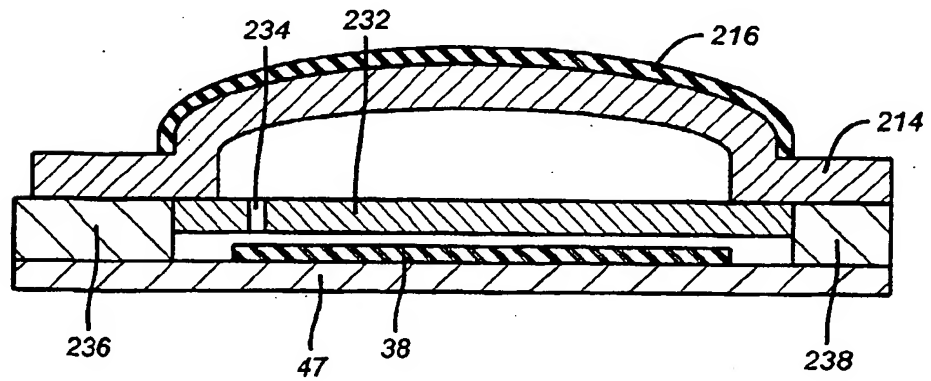
**FIG. 21**



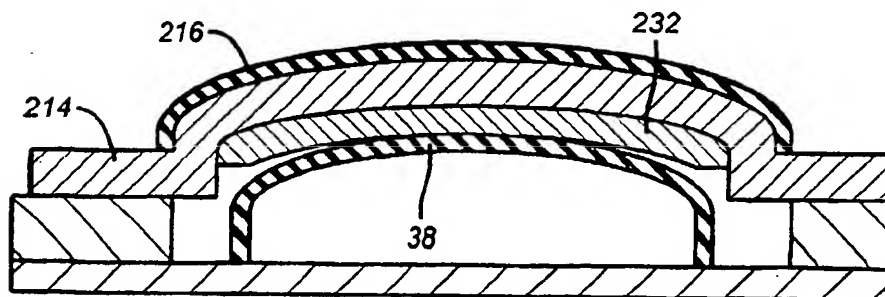
**FIG. 22**



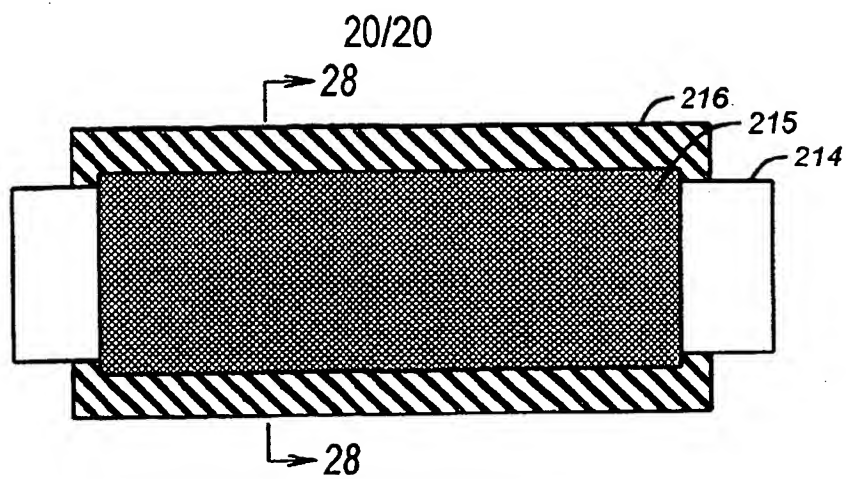
**FIG. 23**



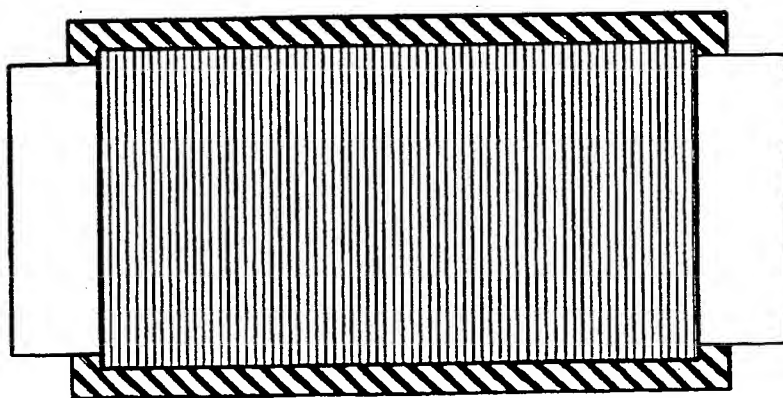
**FIG. 24**



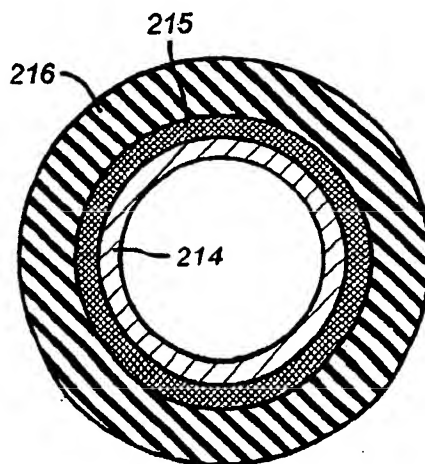
**FIG. 25**



**FIG. 26**



**FIG. 27**



**FIG. 28**

1     **TITLE: EXPANDABLE PACKER ISOLATION SYSTEM**

2

3     **FIELD OF THE INVENTION**

4     The field of this invention is one-trip completion  
5     systems, which allow for zone isolation and  
6     production using a technique for expansion of  
7     screens and isolators, preferably in open hole  
8     completions.

9

10    **BACKGROUND OF THE INVENTION**

11    Typically zonal isolation is desirable in wells with  
12    different pressure regimes, incompatible reservoir  
13    fluids, and varying production life. The typical  
14    solution to this issue in the past has been to  
15    cement and perforate casing. Many applications  
16    further required gravel packing adding an extra  
17    measure of time and expense to the completion. The  
18    cemented casing also required running cement bond  
19    logs to insure the integrity of the cementing job.  
20    It was not unusual for a procedure involving  
21    cemented casing, gravel packing and zonal isolation  
22    using packers to take 5-20 days per zone and cost as  
23    much or over a million dollars a zone. Use of cement  
24    in packers carried with it concerns of spills and  
25    extra trips into the well. Frequently fracturing  
26    techniques were employed to increase well  
27    productivity but cost to complete was also  
28    increased. Sand control techniques, seeking to  
29    combine gravel packing and fracturing, also bring on  
30    risks of unintended formation damage, which could  
31    reduce productivity.

32

1 In open hole completions, gravel packing was  
2 difficult to effectively accomplish although there  
3 were fewer risks in horizontal pay zones. The  
4 presence of shale impeded the gravel packing  
5 operation. Proppant packs were used in open hole  
6 completions, particularly for deviated or horizontal  
7 open hole wells. Proppant packing involved running a  
8 screen in the hole and pumping proppants outside of  
9 it. Proppants such as gravel or ceramic beads were  
10 effective to control cave-ins but still allowed  
11 water or gas coning and breakthroughs. Proppant  
12 packs have been used between activated isolation  
13 devices such as external casing packers in  
14 procedures that were complex, time consuming, and  
15 risky. More recently, a new technique which is the  
16 subject of a co-pending patent application also  
17 assigned to Baker Hughes Incorporated a refined  
18 technique has been developed wherein a proppant pack  
19 is delivered on both sides of a non-activated  
20 annular seal. In this technique the seal can  
21 thereafter be activated against casing or open hole.  
22 While this technique involved improved zonal  
23 isolation, it was still costly and involved complex  
24 delivery tools and techniques for the proppant.

25  
26 Shell Oil Company has disclosed more recently,  
27 techniques for expansion of slotted liners using  
28 force driven cones. Screens have been mechanically  
29 expanded, in an effort to eliminate gravel packing  
30 in open hole completions. The use of cones to expand  
31 slotted liners suffered from several weaknesses. The  
32 structural strength of the screens or slotted liners

1 being expanded suffered as a tradeoff to allow the  
2 necessary expansion desired. When placed in service  
3 such structures could collapse at differential  
4 pressures on expanded screens of as low as 2-300  
5 pounds per square inch (PSI). Expansion techniques  
6 suffered from other shortcomings such as the  
7 potential for rupture of a tubular or screen upon  
8 expansion. Additionally, where the well bore is  
9 irregular the cone expander will not apply uniform  
10 expansion force to compensate for void areas in the  
11 well bore. This can detract from seal quality. Cone  
12 expansion results in significant longitudinal  
13 shrinkage, which potentially can misalign the screen  
14 being expanded from the pay zone, if the initial  
15 length is sufficiently long. Due to longitudinal  
16 shrinkage, overstress can occur particularly when  
17 expanding from bottom up. Cone expansions also  
18 require high pulling forces in the order of 250,000  
19 pounds. Slotted liner is also subject to relaxation  
20 after expansion. Cone expansions can give irregular  
21 fracturing effect, which varies with the borehole  
22 size and formation characteristics.

23  
24 Accordingly the present invention has as its main  
25 objective the ability to replace traditional  
26 cemented casing completion procedures. This is  
27 accomplished by running isolators in pairs for each  
28 zone to be produced with a screen in between. The  
29 screen and isolators are delivered in a single trip  
30 and expanded down hole using an inflatable device  
31 to preferably expand the isolators. The screens can  
32 also be similarly expanded using an inflatable tool



1 or by virtue of mechanical expansion, depending on  
2 the application. Each zone can be isolated in a  
3 single trip. The completion assembly and the  
4 expansion tool can selectively be run in together or  
5 on separate trips. These and other features of the  
6 invention can be more readily understood by a review  
7 of the description of the preferred embodiment,  
8 which appears below.

#### 9 10 **SUMMARY OF THE INVENTION**

11 A completion technique to replace cementing casing,  
12 perforating, fracturing, and gravel packing with an  
13 open hole completion is disclosed. Each zone to be  
14 isolated by the completion assembly features a pair  
15 of isolators, which are preferably tubular with a  
16 sleeve of a sealing material such as an elastomer on  
17 the outer surface. The screen is preferably made of  
18 a weave in one or more layers with a protective  
19 outer, and optionally an inner, jacket with  
20 openings. The completion assembly can be lowered on  
21 rigid or coiled tubing which, internally to the  
22 completion assembly, includes the expansion  
23 assembly. The expansion assembly is preferably an  
24 inflatable design with features that provide limits  
25 to the delivered expansion force and/or diameter. A  
26 plurality of zones can be isolated in a single trip.

#### 27 28 **DETAILED DESCRIPTION OF THE DRAWINGS**

29 Figures 1a-d, are a sectional elevation view of the  
30 open hole completion assembly at the conclusion of  
31 running in;

1     Figures 2a-d, are a sectional elevation view of the  
2     open hole completion assembly showing the upper  
3     optional packer in a set position;  
4     Figures 3a-d, are a sectional elevation view of the  
5     open hole completion assembly with a zone isolated  
6     at its lower end;  
7     Figures 4a-d, are a sectional elevation view of the  
8     open hole completion assembly with a zone isolated  
9     at its upper end;  
10    Figures 5a-d, are a sectional elevation of the open  
11    hole completion assembly in the production mode;  
12    Figure 6 is a sectional elevation view of the  
13    circulating valve of the expansion assembly;  
14    Figure 7 is a sectional view elevation of the  
15    inflation valve mounted below the circulating valve;  
16    Figures 8a-b are a sectional elevation view of the  
17    injection control valve mounted below the  
18    circulating valve;  
19    Figures 9a-b are a sectional elevation view of the  
20    inflatable expansion tool mounted below the  
21    injection control valve;  
22    Figure 10 is a sectional elevation view of the drain  
23    valve mounted below the inflatable expansion tool;  
24    Figure 11 a detail of a first embodiment of the  
25    sealing element on an isolator in the run in  
26    position;  
27    Figure 12 is the view of Fig. 11 in the set  
28    position;  
29    Figure 13 is a second alternative isolator seal in  
30    the run in position;  
31    Figure 14 is the view of Fig. 13 in the set  
32    position;

1 Figure 15 is a third alternative isolator seal in  
2 the run in position featuring end sleeves;  
3 Figure 16 is a detail of an end sleeve shown in Fig.  
4 15;  
5 Figure 17 is the view of Fig. 15 in the set  
6 position;  
7 Figure 18 is a fourth alternative isolator seal  
8 showing a filled cavity beneath it, in the run in  
9 position;  
10 Figure 19 is the view of Fig. 18 in the set  
11 position;  
12 Figure 20 is the view taken along line 20-20 shown  
13 in Fig. 19;  
14 Figure 21 illustrates a sectional elevation view of  
15 an undulating seal on the isolator in the run in  
16 position;  
17 Figure 22 is the view of Fig. 21 in the set  
18 position;  
19 Figure 23 is another alternative isolator with a  
20 wall re-enforcing feature shown in section during  
21 run-in;  
22 Figure 24 is the view of Fig. 23 after the mandrel  
23 has been expanded;  
24 Figure 25 is the view of Fig. 24 after expansion of  
25 an insert sleeve with the bladder.  
26 Figure 26 is a section view of an unexpanded  
27 isolator showing travel limiting sleeve;  
28 Figure 27 is the view of Fig. 26 after maximum  
29 expansion of the isolator; and  
30 Figure 28 is the view at line 28-28 of Fig. 26.  
31  
32 **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

1 Referring to Figs. 1a-d, the completion assembly C  
2 is illustrated in the run in position in well bore  
3 10. At its lower end, as seen in Figs. 1d-5d are a  
4 wash down shoe 12 and a seal sub 14 both of known  
5 design and purpose. Working up-hole from seal sub 14  
6 are a pair of isolators 16 and 18 which are spaced  
7 apart to allow mounting a screen assembly 20 in  
8 between. Further up-hole is a section of tubular 22  
9 whose length is determined by the spacing of the  
10 zones to be isolated in the well bore 10. Further  
11 up-hole is another set of isolators 24 and 26 having  
12 a screen assembly 28 in between. Optionally at the  
13 top of the completion assembly C is a packer 30,  
14 which is selectively settable against the well bore  
15 10, as shown in Fig. 2a. Those skilled in the art  
16 will appreciate that the completion assembly  
17 described is for isolation of two distinct producing  
18 zones. The completion assembly C can also be  
19 configured for one zone or three or more zones by  
20 repeating the pattern of a pair of isolators above  
21 and below a screen for each zone.  
22  
23 The completion assembly C can be run in on an  
24 expansion assembly E. Located on the expansion  
25 assembly E is a setting tool 32 which supports the  
26 packer 30 and the balance of the completion assembly  
27 C for run in. Ultimately, the setting tool 32  
28 actuates the packer 30 in a known manner. The  
29 majority of the expansion assembly E is nested  
30 within the completion assembly C for run in. At the  
31 lower end 34 of the expansion assembly E, there is  
32 engagement into a seal bore 36 located in seal sub

1 14. If this arrangement is used, circulation during  
2 run in is possible as indicated by the arrows shown  
3 in Figs. 1a-d.

4  
5 The expansion assembly E shown in Figs. 1a-d through  
6 5a-d is illustrated schematically featuring an  
7 expanding bladder 38. The bladder 38 is shown above  
8 the seal bore 36 in an embodiment where flow through  
9 the expansion assembly E can exit its lower end 34.  
10 In a known manner one or more balls can be dropped  
11 to land below the bladder 38 so that it can be  
12 selectively inflated and deflated at desired  
13 locations. While this is one way to actuate the  
14 bladder 38, the preferred technique is illustrated  
15 in Figs. 6-10. Using the equipment shown in these  
16 Figures, the placement of the seal bore 36 will need  
17 to be above the bladder 38, as will be explained  
18 below.

19  
20 At this point, the overall process can be readily  
21 understood. The completion assembly C is supported  
22 off of the expansion assembly E for running in to  
23 the well bore in tandem on rigid or coiled tubing  
24 40. The setting tool 32 engages the packer 30 for  
25 support. Circulation is possible during run in as  
26 flow goes through the expansion assembly E and, in  
27 the preferred embodiment shown in Fig. 7, exits  
28 laterally through the inflation valve 42 at ports 44  
29 which are disposed below a seal bore such as 36. It  
30 should be noted that the inflation valve 42 (see  
31 Fig. 7) is disposed above screen expansion tool 47  
32 (see Figs. 9a-b), which comprises the bladder 38.

1 During run in, the bladder 38 is deflated and  
2 circulation out of ports 44 goes around deflated  
3 bladder 38 and out through wash down shoe 14, or an  
4 equivalent lower outlet, and back to the surface  
5 through annulus 46.

6 The packer 30 is set using the setting tool 32, in a  
7 known manner which puts a longitudinal compressive  
8 force on element 48 pushing it against the well bore  
9 10, closing off annulus 46 (as shown in Fig. 2a).

10 The use of packer 30 is optional and other devices  
11 can be used to initially secure the position of  
12 completion assembly C prior to expansion, without  
13 departing from the invention.

14 The expansion assembly is then actuated from the  
15 surface to inflate bladder 38 so as to diametrically  
16 expand the lowermost isolator 16, followed by screen  
17 20, isolator 18, and, if present, isolator  
18 24, followed by screen 28, and isolator 26. These  
19 items can be expanded from bottom to top as  
20 described or in a reverse order from top to bottom  
21 or in any other desired sequence without departing  
22 from the invention. The expansion technique involves  
23 selective inflation and deflation of bladder 38  
24 followed by a repositioning of the expansion  
25 assembly E until all the desired zones are isolated  
26 by expansion of a pair of isolators above and below  
27 an expanded screen. The number of repositioning  
28 steps is dependent on the length of bladder 38 and  
29 the length and number of distinct isolation  
30 assemblies for the respective zones to be isolated.  
31 Fig.3c shows the lower screen 20 and the lowermost  
32 isolator 16 already expanded. Fig. 4b shows the

1 upper screen 28 being expanded, while Figs. 5a-d  
2 reveal the conclusion of expansion which results in  
3 isolation of two zones, or stated differently, two  
4 production locations in the well bore 10. This  
5 Figure also illustrates that the expansion assembly  
6 E has been removed and a production string 50 having  
7 lower end seals 52 has been tagged into seal bore 54  
8 in packer 30. It should be noted that tubular 22  
9 has not been expanded as it lies between the zones  
10 of interest that require isolation.

11 Now that the overall method has been described, the  
12 various components, which make up the preferred  
13 embodiment of the expansion assembly E, will be  
14 further explained with reference to Figs. 6-10.  
15 Going from up-hole to down hole the expansion  
16 assembly E comprises: a circulating valve 56 (see  
17 Fig. 6); an inflation valve 42 (see Fig. 7); an  
18 injection control valve 58 (see Figs. 8a-b); an  
19 inflatable expansion tool 47 (see Figs. 9a-b); and a  
20 drain valve 60 (see Fig. 10).

21 The purpose of the circulating valve 56 is to serve  
22 as a fluid conduit during the expansion and  
23 deflation of the bladder 38. It comprises a top sub  
24 62 having an inlet 64 leading to a through passage  
25 66. A piston 68 is held in the position shown by one  
26 or more shear pins 70. Housing 72 connects a  
27 bottom sub 74 to the top sub 62. Seals 76 and 78  
28 straddle opening 80 in housing 72 effectively  
29 isolating opening 80 from passage 66. A ball seat 82  
30 is located on piston 68 to eventually catch a ball  
31 (not shown) to allow breaking of shear pins 70 and a  
32 shifting of piston 68 to expose opening or openings

1     80. The main purpose of the circulating valve 56 is  
2     to allow drainage of the string as the expansion  
3     assembly E is finally removed from the well bore 10  
4     at the conclusion of all the required expansions.  
5     This avoids the need to lift a long fluid column  
6     that would otherwise be trapped inside the tubing  
7     40, during the trip out of the hole.  
8     The next item, mounted just below the circulating  
9     valve 56, is the inflation valve 42. It is  
10    illustrated in the run in position. It has a top sub  
11    84 connected to a dog housing 86, which is in turn  
12    connected to a bottom sub 88. A body 90 is mounted  
13    between the top sub 84 and the bottom sub 88 with  
14    seal 92 disposed at the lower end of annular cavity  
15    94. A piston 95, having a groove 96, is disposed in  
16    annular cavity 94. Body 90 supports ball seat 97 in  
17    passage 98. Body 90 has a lateral passage 100 to  
18    provide fluid communication between passage 98 and  
19    piston 95. A shear pin or pins 102 secure the  
20    initial position of piston 95 to dog housing 86.  
21    Body 90 also has lateral openings 104 and 106 while  
22    dog housing 86 has a lateral opening 44 near opening  
23    106. At the top of piston 95 are seals 108 and 110  
24    to allow for pressure buildup above piston 95 in  
25    passage 98 when a ball (not shown) is dropped onto  
26    ball seat 97. Mounted to dog housing 86 are locking  
27    dogs 112 which are biased into groove 96 when it  
28    presents itself opposite dogs 112. Biasing is  
29    provided by a band spring 114.  
30    The operation of the inflation valve 42 can now be  
31    understood. During run in, passage 98 is open down  
32    to lateral opening 106. Since passage 98 is



1 initially obstructed in injection control valve 58,  
2 for reasons to be later explained, flow into passage  
3 98 exits the dog housing 86 through lateral  
4 openings 106 (in body 90) and lateral opening 44 (in  
5 dog housing 86). Since opening 44 is below a seal  
6 bore (such as 36) mounted to the completion assembly  
7 C flow from the surface will, on run in, go through  
8 the circulating valve 56 and through passage 98 of  
9 inflation valve 42 and finally exit at port 44 for  
10 conclusion of the circulation loop to the surface  
11 through annulus 46. Dropping a ball (not shown) onto  
12 ball seat 97 allows pressure to build on top of  
13 piston 95, which breaks shear pin 102 as piston 95  
14 moves down. This downward movement allows flow to  
15 bypass the now obstructed ball seat 97 by moving  
16 seals 108 and 110 below lateral port 104. At the  
17 same time, lateral port 44 is obstructed as seal 116  
18 passes port 106 in body 90. The movement of piston  
19 95 is locked as dogs 112 are biased by band spring  
20 114 into groove 96. Pressure from the surface, at  
21 this point, is directed into the injection control  
22 valve 58.

23  
24 The injection control valve 58 comprises a top sub  
25 118 connected to a valve mandrel 120 at thread 122.  
26 Valve mandrel 120 is connected to spring mandrel 124  
27 at thread 126. Spring mandrel 124 is connected to  
28 sleeve adapter 128 at thread 130. Sleeve adapter 128  
29 is connected to bottom sub 132 at thread 134. Wedged  
30 between valve mandrel 120 and top sub 118 are  
31 perforated sleeve 136 and plug 138. Seal 140 is used  
32 to seal plug 138 to valve mandrel 120. Flow entering

1 passage 142 from passage 98 in the inflation valve  
2 42 passes through openings 144 in perforated sleeve  
3 136 and through lateral passage 146 in valve mandrel  
4 120. This happens because plug 138 obstructs passage  
5 142 below openings 144. Piston 148 fits over valve  
6 mandrel 120 to define an annular passage 150, the  
7 bottom of which is defined by seal adapter 152,  
8 which supports spaced seals 154 and 156. In the  
9 initial position, seals 154 and 156 straddle passage  
10 158 in valve mandrel 120. A pressure buildup in  
11 annular passage 150 displaces piston 148 and moves  
12 seal 154 past passage 158 to allow flow to bypass  
13 plug 138 through a flow path which includes openings  
14 144, passage 146, passage 158, and eventually out  
15 bottom sub 132. At the same time spring 160 is  
16 compressed by seal adapter 152, which moves in  
17 tandem with piston 148. Seals 154 and 156 wind up  
18 straddling passage 162 in valve mandrel 120. This  
19 prevents escape of fluid out through passage 164 in  
20 seal adapter 152. Accordingly, fluid flow initiated  
21 from the surface will flow through injection control  
22 valve 58 after sufficient pressure has displaced  
23 piston 148. Such flow will proceed into inflatable  
24 expansion tool 47. Upon removal of surface pressure,  
25 spring 160 displaces seals 154 and 156 back above  
26 passage 162 to allow pressure to be bled off through  
27 passage 164 to allow bladder 38 to deflate, as will  
28 be explained below.

29

30 Referring now to Figs. 9a-b, the structure and  
31 operation of the inflatable expansion tool 47 will  
32 now be described. A top sub 168 is connected to a

1 mandrel 170 and a bottom sub 172 is connected to the  
2 lower end of the mandrel 170. Bladder 38 is retained  
3 in a known manner to mandrel 170 by a fixed  
4 connection at seal adapter 174 at its upper end and  
5 by a movable seal adapter 176 at its lower end. Seal  
6 adapter 176 is connected to spring housing 178 to  
7 define a variable volume chamber 180 in which are  
8 mounted a plurality of Belleville washers 182. A  
9 stop ring 184 is mounted to mandrel 170 in a manner  
10 where it is prevented from moving up-hole. Passages  
11 186 and 187 communicate pressure in central passage  
12 188 through the mandrel 170 and under bladder 38 to  
13 inflate it. In response to pressure below the  
14 bladder 38, there is up-hole longitudinal movement  
15 of seal adapter 176 and spring housing 178. Since  
16 stop ring 184 can't move in this direction, the  
17 Belleville washers get compressed. Outward expansion  
18 of bladder 38 can be stopped when all the Belleville  
19 washers have been pressed flat. Other techniques for  
20 limiting the expansion of bladder 38 will be  
21 described below. What remains to be described is  
22 the drain valve 60 shown in Fig. 10. It is this  
23 valve that creates the back- pressure to allow  
24 bladder 38 to expand.

25  
26 The drain valve 60 has a top sub 190 connected to an  
27 adapter 192, which is, in turn, connected to housing  
28 194 followed, by a bottom sub 196. A piston 198 is  
29 connected to a restrictor housing 200 followed by a  
30 seal ring seat 202. Restrictor housing 200 supports  
31 a restrictor 204. Spring 206 bears on bottom sub 196  
32 and exerts an up-hole force on piston 198. Seal 208

1 forces flow through restrictor 204 producing back-  
2 pressure, which drives the expansion of bladder 38.  
3 Initially flow will proceed through restrictor 204  
4 into passage 210 and around spring 206 and between  
5 seal ring seat 202 and seal ring insert 212. This  
6 flow situation will only continue until there is  
7 contact between seal ring seat 202 and seal ring  
8 insert 212. At that time flow from the surface stops  
9 and applied pressure from surface pumps is applied  
10 directly under bladder 38. One reason to cut the  
11 flow from drain valve 60 is to prevent pressure  
12 pumping into the formation below, which can have a  
13 negative affect on subsequent production. When the  
14 surface pumps are turned off, a gap reopens between  
15 seal ring seat 202 and seal ring insert 212. Some  
16 under bladder pressure can be relieved through this  
17 gap. Most of the accumulated pressure will bleed off  
18 through passage 164 in the injection control valve  
19 58 (see Fig. 8a) in the manner previously described.

20  
21 Those skilled in the art can now see how by  
22 selective inflation and deflation of bladder 38 the  
23 isolators and screens illustrated in Figs. 1a-d can  
24 be expanded in any desired order.

25 Some of the features of the invention are the  
26 various designs for the expandable isolator, such as  
27 isolator 26, as illustrated in Figs. 11-22. It  
28 should be noted that the isolator depicted in Figs.  
29 1a-d is not an inflatable packer in the traditional  
30 sense. Rather it is a tubular mandrel 214 surrounded  
31 by a sealing sleeve 216 wherein inflatable, such as  
32 bladder 38, or other devices are used to expand both

1 mandrel 214 and sleeve 216 together into the open  
2 hole of well bore 10.

3 In the embodiments shown in Figs. 11 and 12 the  
4 sleeve 216 is shown in rubber. There are  
5 circumferential ribs 218 added to prevent rubber  
6 migration or extrusion upon expansion. The expanded  
7 view is illustrated in Fig. 12. In open hole  
8 completions, the ribs 218 dig into the borehole  
9 wall. This assures seal integrity against extrusion.  
10 Ribs 218 can be directly attached to the mandrel 214  
11 or they can be part of a sleeve, which is slipped  
12 over mandrel 214 before the rubber is applied.  
13 Direct connection of ribs 218 can cause locations of  
14 high stress concentration, whereas a sleeve with  
15 ribs 218 mounted to it reduces the stress  
16 concentration effect. Ribs 218 can be applied in a  
17 variety of patterns such as offset spirals. They can  
18 be continuous or discontinuous and they can have  
19 variable or constant cross-sectional shapes and  
20 sizes.

21 A beneficial aspect of ribs 39 in bladder 38 (see  
22 Fig. 9a) is that their presence helps to reduce  
23 longitudinal shortening of mandrel 214 and sleeve  
24 216 as they are diametrically expanded. Limiting  
25 longitudinal shrinkage due to expansion is a  
26 significant issue when expanding long segments  
27 because a potential for a misalignment of the screen  
28 and surrounding isolators from the zone of interest.  
29 This effect can happen if there is significant  
30 longitudinal shrinkage, which is a more likely  
31 occurrence if there is a mechanical expansion with a  
32 cone.

1  
2 The expansion techniques can be a combination of an  
3 inflatable for the isolators and a cone for  
4 expansion of screens. This hybrid technique is most  
5 useful for cone expanding long screen sections while  
6 the isolators above and below are expanded with a  
7 bladder. The isolators require a great deal of force  
8 to assure seal integrity making the application of  
9 inflatable technology most appropriate. The  
10 inflation pressure for a bladder 38 disposed inside  
11 an isolator can be monitored at the surface. The  
12 characteristic pressure curve rises steeply until  
13 the mandrel starts to yield, and then levels off  
14 during the expansion process, and thereafter there  
15 is a subsequent spike at the point of contact with  
16 the formation or casing. It is not unusual to see  
17 the plateau at about 6,000 PSI with a spike going as  
18 high as 8500 PSI. Use of pressure intensifiers  
19 adjacent the bladder 38, as a part of the expansion  
20 assembly E, allows the up-hole equipment to operate  
21 at lower pressures to keep down equipment costs. The  
22 ability to monitor and control inflation pressure  
23 can be a control technique to regulate the amount of  
24 expansion in an effort to avoid mandrel failure or  
25 overstressing the formation. Another monitoring  
26 technique for real time expansion is to put strain  
27 sensors in the isolator mandrels and use known  
28 signal transmission techniques to communicate such  
29 information to the surface in real time. Yet another  
30 technique for limitation of expansion can be control  
31 of the volume of incompressible fluid delivered  
32 under the bladder 38. Another technique can be to

1     apply longitudinal corrugations to the mandrel 214,  
2     such that the size it will expand to when rounded by  
3     an inflatable is known.

4  
5     Referring now to Figs. 13 and 14, another approach  
6     to limiting extrusion of sealing sleeve 216 upon  
7     expansion by a bladder 38, is to put reinforcing  
8     ribs 220 in whole or in part at or near the upper  
9     and/or lower ends of the sealing sleeve 216. Their  
10    presence creates an increased force into the open  
11    hole to reduce end extrusion, as shown in Fig. 14.

12  
13    In Figs. 15-17, the anti-extrusion feature is a pair  
14    of embedded rings 221 that run longitudinally in  
15    sleeve 216. The stiffness of each ring 221 can be  
16    varied along its length, from strongest at the ends  
17    of sleeve 216 to weaker toward its middle. One way  
18    to do this is to add bigger holes 222 closer to the  
19    middle of sleeve 216 and smaller holes 224 nearer  
20    the ends, as shown in Fig. 16. Another way is to  
21    vary the thickness.

22  
23    In Figs. 18-20, another variation is shown which  
24    involves a void space 226 between the mandrel 214  
25    and the sleeve 216. This space can be filled with a  
26    deformable material, or a particulate material, such  
27    as proppant, sand, glass balls or ceramic beads 228.  
28    The beneficial features of this design can be seen  
29    after there is expansion in an out of round open  
30    hole, as shown in Fig. 20. Where there is a short  
31    distance to expand to the nearby borehole wall,  
32    contact of sleeve 216 occurs sooner. This causes a

1 displacement of the filler 228 so that the regions  
2 with greater borehole voids can still be as tightly  
3 sealed as the regions where contact is first made.  
4 This configuration, in particular, as well as the  
5 other designs for isolators discussed above offers  
6 an advantage over mechanical expansion with a cone.  
7 Cone expansion applies a uniform circumferential  
8 expansion force regardless of the shape of the  
9 borehole. The inflate technique conforms the applied  
10 force to where the resistance appears. Expansions  
11 that more closely conform to the contour of the well  
12 bore can thus be accomplished. Use of the void 226  
13 with filler 228 merely amplifies this inherent  
14 advantage of expansion with a bladder 38. Those  
15 skilled in the art will appreciate that the shorter  
16 the bladder 38, the greater is the ability of the  
17 isolator to be expanded in close conformity with the  
18 borehole configuration. On the other hand, a  
19 shorter bladder also requires more cycles for  
20 expansion of a given length of isolator or screen.  
21 Longer bladders not only make the expansion go  
22 faster, but also allow for greater control of  
23 longitudinal shrinkage. Here again, the ability to  
24 control longitudinal shrinkage will have a tradeoff.  
25 If the mandrel 214 is restrained from shrinking as  
26 much longitudinally its wall thickness will decrease  
27 on diametric expansion. Compensation for this  
28 phenomenon by merely increasing the initial wall  
29 thickness of the mandrel 214 creates the problem of  
30 greatly increasing the required expansion pressure.  
31



1 A solution is demonstrated in Figs. 23-25. In these  
2 Figures, the mandrel 214 still has the sleeve 216.  
3 Internally to mandrel 214 is a seal bore 230, which  
4 can span the length of the sleeve 216. Within the  
5 seal bore 230, the inflatable expansion tool 47 is  
6 inserted. The inflatable expansion tool 47 has been  
7 modified to have a bladder 38 and an insert sleeve  
8 232 with a port 234 all mounted between two body  
9 rings 236 and 238. Initially, as shown in Fig. 24,  
10 fluid pressure expands the mandrel 214 against the  
11 borehole through port 234. Then the bladder 38 is  
12 expanded to push the sleeve 232 against the already  
13 expanded mandrel 214 (see Fig. 25).

14

15 Yet another technique for improving the sealing of  
16 an isolator is to take advantage of the greater  
17 coefficient of thermal expansion in the sleeve 216  
18 such as when it is made of rubber. If the rubber is  
19 pre-cooled prior to running into the well bore it  
20 will grow in size as it comes to equilibrium  
21 temperature even after it has been inflatably  
22 expanded. The subsequent expansion increases sealing  
23 load. Thus rather than over-expanding the formation  
24 in-order to store elastic energy in it, the use of a  
25 mandrel 214 with a thin rubber sleeve 216 allows  
26 storage of elastic strain in the rubber itself.  
27 Although rubber has been mentioned for sleeve 216  
28 other resilient materials compatible with down hole  
29 temperatures, pressures and fluids can be used  
30 without departing from the invention.

31

1 The screens, such as 28 can have a variety of  
2 structures and can be a single or multi-layer  
3 arrangement. In Fig.1b, the screen 28 is shown as a  
4 sandwich of a 250-micron membrane 240 between inner  
5 242 and outer 244 jackets. These jackets are  
6 perforated or punched and the membrane itself can be  
7 a plurality of layers joined to each other by  
8 sintering or other joining techniques. The advantage  
9 of the sandwich is to minimize relative expansion as  
10 well as to protect the membrane 240.

11  
12 Yet another isolator configuration is visible in  
13 Figs. 21-22. Here the mandrel 214 has a wavy  
14 configuration one embodiment of which is a  
15 circumferential ribbed appearance. The sleeve 216 is  
16 applied to have a cylindrical exterior surface.  
17 After expansion, as seen in Fig. 22, the mandrel 214  
18 becomes cylindrically shaped while the sleeve takes  
19 on a wavy exterior shape with peaks where the  
20 mandrel 214 had valleys, in its pre-expanded state.

21  
22 Yet another issue resolved by the present invention  
23 is how to limit expansion of the isolators in a  
24 radial direction. Unrestrained growth can result in  
25 rupture if the elongation limits of the mandrel 214  
26 are exceeded. Additionally, excessive loads on the  
27 formation can fracture it excessively adjacent the  
28 isolator. Expansion limiting devices can be applied  
29 to the isolator itself or to the fluid expansion  
30 tool used to increase its diameter. In one example,  
31 the mandrel 214 is wrapped in a sleeve 215 made of a  
32 biaxial metal weave before the rubber is applied.

1 This material is frequently used as an outer jacket  
2 for high- pressure industrial hose. It allows a  
3 limited amount of diametric expansion until the  
4 weave "locks up" at which time further expansion is  
5 severely limited in the absence of a dramatic  
6 increase in applied force. This condition can be  
7 monitored from the surface so as to avoid over-  
8 expansion of the isolator.

9  
10 As an expanding-mandrel packer is radially expanded  
11 outwards it is desirable to have a mechanism in  
12 place to limit the radial growth of the packer. If  
13 the packer is allowed to expand without restraint of  
14 some kind it will ultimately rupture once the  
15 elongation limit of the mandrel material is  
16 exceeded. Also, if the packer is allowed to place  
17 an excessive load against an open hole formation  
18 wall the formation may be damaged and caused to  
19 fracture adjacent to the packer. There needs to be  
20 an expansion limiting mechanism in either the  
21 packer, such as isolator 16, or expansion device,  
22 such as expansion assembly E.

23  
24 If the expanding-mandrel packer is being expanded  
25 using an inflatable packer (i.e. using hydraulic  
26 pressure), once the yield point of the material is  
27 exceeded and the mandrel deforms plastically,  
28 pressure indications of the amount of radial  
29 expansion is impossible. Therefore, it is desirable  
30 that once a pre-determined level of expansion is  
31 obtained there is a pressure indication that would  
32 indicate the packer is at its maximum design limit.

1 An increase in applied pressure would be obtained if  
2 at some point the packer is subjected to an  
3 increased mechanical force opposing additional  
4 expansion.

5  
6 The expansion of the packer may be limited by  
7 wrapping a bi-axial metal weave sleeve over the  
8 mandrel (see Fig. 26) prior to adding the sealing  
9 medium 216 (i.e. rubber). The bi-axial sleeve 215  
10 will grow circumferentially as the packer mandrel is  
11 expanded, however at a pre-determined diameter the  
12 bi-axial sleeve will "lock-up" (see Fig. 27),  
13 preventing any additional radial expansion of the  
14 mandrel without a significant increase in applied  
15 radial load from the expansion device. This could  
16 give an indication at the surface that the limiting  
17 diameter of the packer has been reached, and further  
18 expansion is ceased.

19  
20 The bi-axial mesh sleeve 215 would be fabricated in  
21 a tubular shape, and would be installed over the  
22 expanding-mandrel 214 during assembly of the packer.  
23 The mesh sleeve 215 would be in the un-expanded  
24 condition at this time. A rubber sealing cover 216  
25 would then be applied over the bi-axial sleeve 215  
26 to serve as the sealing component as the packer is  
27 expanded radially against the open-hole or casing.  
28 The assembled packer cross section is shown in Fig.  
29 28.

30  
31 As the packer is expanded in the borehole, the bi-  
32 axial mesh sleeve 215 expands circumferentially

1 along with the packer mandrel 214. The rubber cover  
2 216 is also expanding at this time. Once a pre-  
3 determined amount of expansion is obtained however  
4 the weaved metal fibers in the bi-axial sleeve will  
5 reach a configuration where further expansion is not  
6 possible, without breaking the fibers in the mesh.  
7 This will result in additional resistance to radial  
8 expansion, which will be detected by an increase in  
9 applied pressure required for additional expansion.  
10 At this point attempts at further expansion is  
11 ceased.

12  
13 Fig. 27 shows the condition of the packer after  
14 reaching the expansion limit of the packer, as  
15 dictated by the maximum diametrical growth limit of  
16 the bi-axial mesh sleeve 215. The fiber orientation  
17 in the mesh sleeve is more in a perpendicular  
18 orientation to the long axis of the packer than  
19 before expansion was started. The amount of  
20 expansion possible in these mesh sleeves is dictated  
21 by the wrapping pattern used, and can be varied to  
22 allow various expansion potentials.

23  
24 The amount of expansion of bladder 38 can also be  
25 limited by regulation of volume delivered to it by  
26 measuring the flow going in or by delivering fluid  
27 from a reservoir having a known volume. Typically  
28 the isolators and screens of the present invention  
29 will have to be expanded up to 25%, or more, to  
30 reach the borehole. This requires materials with  
31 superior ductility and toughness. Some acceptable  
32 materials are austenitic stainless steels, such as

1 304L or 316L, super austenitic stainless steel (Alloy  
2 28), and nickel based alloys (Inconel 825). As much  
3 as a 45% elongation can be achieved by using these  
4 materials in their fully annealed state. These  
5 materials have superior corrosion resistance  
6 particularly in chlorides or in sour gas service,  
7 although some of the materials perform better than  
8 others. Inconel 825 is very expensive which may rule  
9 it out for long intervals. In vertical wells with  
10 short zones this cost will not normally be an issue.

11

12 The sequence of expansion can also have an effect on  
13 the overall system performance of the isolators. A  
14 desirable sequence can begin with an upper isolator  
15 followed by a screen expansion followed by expansion  
16 of the lower isolator. Simultaneous expansion of the  
17 isolators and screen should be avoided because of  
18 the potentially different pressure responses, which,  
19 in turn, can cause either under or over expansion of  
20 the isolators, which, in turn, can cause inadequate  
21 sealing or formation fracturing.

22

23 When an isolator, such as 16, is expanded, the  
24 sealing integrity can be checked. This can be  
25 accomplished using the expansion assembly E  
26 illustrated in Figs. 6-10. After expansion of the  
27 bladder 38, which sets isolator 16, the bladder 38  
28 is allowed to deflate by removal of pressure from  
29 the surface. Thereafter, flow from the surface is  
30 resumed with bladder 38 still in position inside the  
31 now expanded isolator 16. The injection control  
32 valve 58 is opened by flow through it, which

1 ultimately exits through the drain valve 60. Due to  
2 creation of backpressure by virtue of restrictor 204  
3 (see Fig. 10) the bladder re-inflates inside the  
4 expanded mandrel 214 of the isolator 16. A seal is  
5 created between the completion assembly C and the  
6 expansion assembly E. Since there is an exit point  
7 at wash down shoe 14 and the isolator 16 is already  
8 expanded against the well bore 10, applied pressure  
9 from the surface will go back up the annulus 46  
10 until it encounters the sealing sleeve 216, which is  
11 now firmly engaging the bore hole wall 10. The  
12 annulus 46 is monitored at the surface to see if any  
13 returns arrive. Absence of returns indicates the  
14 seal of isolator 16 is holding. It should be noted  
15 that conducting this test puts pressure on the  
16 formation for a brief period. It should also be  
17 noted that the other isolators could be checked for  
18 leakage in a similar manner. For example, isolator  
19 18 can be checked with bladder 38 re-inflated and  
20 flow through the expansion assembly E, which exits  
21 through screen 20 and exerts pressure against a  
22 sealing sleeve 216 of isolator 18.

23  
24 As previously mentioned, it may be desirable to  
25 combine the inflatable technique with a mechanical  
26 expansion technique using a cone expander. The  
27 driven cone technique may turn out to be more useful  
28 in expanding the screen, since substantially less  
29 force is required. Cone expansion is a continuous  
30 process and can be accomplished much faster for the  
31 screens, which are typically considerably longer  
32 than the isolators. When it comes to the isolators,

1 the cone expansion technique has some serious  
2 drawbacks. Since the isolators must be expanded in  
3 open hole or casing in order to obtain a seal with a  
4 force substantial enough for sealing, greater  
5 certainty is required that such a seal has been  
6 accomplished than can be afforded with cone  
7 expansion techniques. In open hole applications, the  
8 exact diameter of the hole is unknown due to  
9 washouts, drill pipe wear of the borehole, and other  
10 reasons. In cased hole applications, there is the  
11 issue of manufacturing tolerances in the casing. If  
12 the casing is slightly oversized, there will be  
13 insufficient sealing using a cone of a fixed  
14 dimension. There may be contact by the sealing  
15 sleeve 216 but with insufficient force to hold back  
16 the expected differential pressures. On the other  
17 hand, if the casing is undersized, the isolator may  
18 provide an adequate seal but the amount of realized  
19 expansion may be too small to allow the cone driver  
20 to pass through. If driving from bottom to top there  
21 will be a solid lockup, which prevents removal of  
22 the cone driver from the well. If driving from top  
23 to bottom the isolator will not be able to expand  
24 over its entire length. A solution can be the use of  
25 the expansion assembly E for the isolator expansion  
26 in combination with a cone expansion assembly for  
27 the screens. These two expansion assemblies can be  
28 run in separate trips or can be combined together in  
29 a single assembly, which preferably is run into the  
30 borehole together with the completion assembly C.  
31



1 It is known that drilling fluids can cause a  
2 drilling-induced damage zone immediately around the  
3 well bore 10. Depending on factors such as formation  
4 mechanical properties and residual stresses radial  
5 fractures can be extended as much as two feet into  
6 the formation to bypass the drilling-induced damage  
7 zone. This can be accomplished by over expanding the  
8 screens as they contact the well bore. A stable  
9 fracture presents little or no danger of migration  
10 into the zone sealed by the packers. Thus, for  
11 example in an eight inch well bore an expansion  
12 pressure of about 2500 PSI yields a fracture radius  
13 of about .5 feet, while a pressure of 7600PSI causes  
14 a 1 foot radius fracture. Because of the large  
15 friction existing between the screen and the well  
16 bore wall, multiple radial fractures may be induced  
17 in different directions, not necessarily aligned  
18 with the maximum horizontal stress direction.  
19 Increased fracture density improves well bore  
20 productivity.

21  
22 Those skilled in the art will appreciate that the  
23 techniques described above can result in a savings  
24 in time and expense in the order of 75% when  
25 compared to traditional techniques of cementing and  
26 perforating casing coupled with traditional gravel  
27 packing operations. The system is versatile and can  
28 be accomplished while running coiled tubing because  
29 the expansion technique is not dependent on work  
30 string manipulation as may be needed for a cone  
31 expansion using pushing or pulling on the work  
32 string. Expansion techniques can be combined and

1 can include roller expansion as well as cone or an  
2 inflatable or combinations. The expansion assembly E  
3 can expand both the isolators and the screens.  
4 Another expansion device that can be used is a  
5 swedge. The preferred direction of expansion is  
6 down hole starting from the packer 30 or any other  
7 sealing or anchoring device, which can be used in  
8 its place. The inflatable technique acts to limit  
9 axial contraction when compared to other methods of  
10 expansion due to the axial contact constraint  
11 between the inflatable and isolator or screen during  
12 the expansion process. The sealing sleeve 216 can be  
13 rubber or other materials that are compatible with  
14 conditions down hole and exhibit the requisite  
15 resiliency to provide an effective seal at each  
16 isolator. The formulation of the sleeve can vary  
17 along its length or in a radial direction in an  
18 effort to obtain the requisite internal pressure for  
19 sealing while at the same time limiting extrusion.  
20 Real time feedback can be incorporated into the  
21 expansion procedure to insure sufficient expansion  
22 force and to prevent over-stressing. Stress can be  
23 sensed during expansion and reported to the surface  
24 as the bladder 38 expands. The delivered volume to  
25 the bladder 38 can be controlled or the flow into it  
26 can be measured. The formation can be locally  
27 fractured by screen expansion to compensate for  
28 drilling fluid, which can contaminate the borehole  
29 wall. Using the isolators with tubular mandrels 214  
30 a far greater strength is realized than prior  
31 techniques, which required liners to be slotted to  
32 reduce expansion force while sacrificing collapse

1 resistance. The sandwich screens of the present  
2 invention can withstand differential pressures of 2-  
3 3000 PSI as compared to other structures such as  
4 those expanded by rollers where resistance to  
5 collapse is only in the order of 2-300 PSI.

6 In another expansion technique, the mandrel 214 can  
7 be made from material which, when subjected to  
8 electrical energy increases in dimension to force  
9 the sealing sleeve 216 into sealing contact with the  
10 borehole.

11  
12 The use of an inflatable technique to expand the  
13 isolators and screens allows flexibility in the  
14 direction of expansion i.e. either up-hole or down-  
15 hole. It further allows selective expansion of the  
16 screens, using a variety of techniques, followed by  
17 subsequent isolator expansion by the preferred use  
18 of the expansion assembly E.

19  
20 The length of the inflatable is inversely related to  
21 its sensitivity to borehole variation and is  
22 directly related to the speed with which the  
23 isolator is expanded. The screens can be expanded  
24 with bladder 38 to achieve localized or more  
25 extensive formation fracturing. Overall, higher  
26 forces for expansion can be delivered using the  
27 expansion assembly E than other expansion  
28 techniques, such as cone expansions. The inflatable  
29 technique can vary the force applied to create  
30 uniformity in fracture effect when used in a well  
31 bore with differing hardness or shape variations.

1 The inflatable expansion can be accomplished using a  
2 down hole piston that is weight set or actuated by  
3 an applied force through the work string. If  
4 pressure is used to actuate a down hole piston, a  
5 pressure intensifier can be fitted adjacent the  
6 piston to avoid making the entire work string handle  
7 the higher piston actuation pressures.

8  
9 The isolators can have constant or variable wall  
10 thickness and can be cylindrically shaped or  
11 longitudinally corrugated.

12  
13 The above description is illustrative of the  
14 preferred embodiment and the full scope of the  
15 invention can be determined from the claims, which  
16 appear below.

---

1     Claims:

2

3     1.    A well completion method for isolating at least  
4     one zone, comprising:

5         running into the wellbore a string with at  
6     least one isolator in conjunction with a tool which  
7     allows flow from the surrounding formation into the  
8     string;

9         expanding said isolator and said tool in said  
10    wellbore.

11    2.    The method of claim 1, comprising:  
12         performing said expanding of said isolator and  
13    said tool in a single trip into the wellbore.

14    3.    The method of claim 1, comprising:  
15         running in an anchor with said string;  
16         setting the anchor before said expanding; and  
17         releasing the string from the anchor before  
18    said expanding.

19    4.    The method of claim 1, comprising:  
20         running in an expansion assembly comprising an  
21    inflatable with said string; and  
22         expanding said at least one isolator at least  
23    in part with said inflatable.

24    5.    The method of claim 4, comprising:  
25         selectively deflating and moving said  
26    inflatable for repositioning;  
27         continuing expansion of said at least one  
28    isolator or tool by re-inflating said inflatable  
29    after said repositioning.

30    6.    The method of claim 1, comprising:

1           forming said at least one isolator from an un-  
2           perforated mandrel covered by a resilient sealing  
3           sleeve.

4           7.    The method of claim 6, comprising:  
5                expanding said mandrel from its original size;  
6           and  
7           using at least a partially annealed material for  
8           said mandrel.

9           8.    The method of claim 6, comprising:  
10               limiting the amount of expansion with a device  
11           fitted to said mandrel.

12           9.    The method of claim 8, comprising:  
13                using a woven sleeve around said mandrel that  
14           locks up after a predetermined amount of expansion  
15           of said mandrel as said device.

16           10.   The method of claim 8, comprising:  
17                using a strain sensor as said device;  
18                transmitting, in real time, the sensed strain  
19           to the surface; and

20                determining the amount of expansion from said  
21           sensed strain.

22           11.   The method of claim 6, comprising:  
23                providing radially extending members from said  
24           mandrel into said resilient sealing sleeve to resist  
25           extrusion of said resilient sleeve after expansion  
26           of said mandrel.

27           12.   The method of claim 6, comprising:  
28                providing an embedded ring located adjacent at  
29           least one end of said resilient sleeve to resist  
30           extrusion of said sleeve after expansion of said  
31           mandrel.

32           13.   The method of claim 12, comprising:

1           varying the stiffness of said ring along its  
2   length.

3   14. The method of claim 6, comprising:  
4       providing exterior undulations on said mandrel;  
5       providing a cylindrically shaped outer surface  
6   on said resilient sleeve;  
7       converting said cylindrical shape of the outer  
8   surface of said resilient sleeve to an undulating  
9   shape upon expansion of said mandrel.

10   15. The method of claim 6, comprising:  
11       providing a void between said mandrel and said  
12   resilient sealing sleeve;  
13       placing a deformable material or a particulate  
14   material in said void;  
15       using said deformable material or said  
16   particulate material to aid said resilient sleeve  
17   conform to the wellbore shape on expansion of said  
18   mandrel.

19   16. The method of claim 6, comprising:  
20       pre-cooling said resilient sealing sleeve below  
21   ambient temperature before insertion into the  
22   wellbore.

23   17. The method of claim 1, comprising:  
24       circulating through said string during run in;  
25       closing off circulation passages;  
26       building pressure in said string;  
27       using pressure in said string to expand said at  
28   least one isolator, at least in part.

29   18. The method of claim 1, comprising:  
30       providing an inflatable on said string to  
31   expand said at least one isolator at least in part.

32   19. The method of claim 1, comprising:

1           fully expanding said at least one isolator  
2 solely with at least one inflatable.

3   20. The method of claim 19, comprising:  
4       regulating the volume of incompressible fluid  
5 delivered to said inflatable as a way to limit  
6 expansion of said at least one isolator.

7  
8   21. The method of claim 19, comprising:  
9       using a screen as said tool;  
10       expanding said screen against the wellbore wall  
11 mechanically.

12   22. The method of claim 19, comprising:  
13       using a screen as said tool;  
14       expanding said screen with said inflatable.

15   23. The method of claim 22, comprising:  
16       expanding said at least one isolator and said  
17 screen in a single trip with said inflatable.

18   24. The method of claim 18, comprising:  
19       forming said at least one isolator from an un-  
20 perforated mandrel covered by a resilient sealing  
21 sleeve;

22       initially expanding said mandrel with pressure  
23 and then completing the expansion with said  
24 inflatable.

25   25. The method of claim 22, comprising:  
26       pressure testing, after expansion, the seal of  
27 said at least one isolator through said screen.

28   26. The method of claim 19, comprising:  
29       performing said expanding of said at least one  
30 isolator and said tool in a single trip into the  
31 wellbore.

32   27. The method of claim 26, comprising:



1           running in an anchor with said string;  
2           setting the anchor before said expanding said  
3   inflatable;  
4           releasing the string from the anchor before  
5   actuation of the inflatable;  
6           removing said inflatable from the wellbore with  
7   said string.  
8   28. The method of claim 18, comprising:  
9       forming at least one of said isolators from an  
10   un-perforated mandrel covered by a resilient sealing  
11   sleeve;  
12       initially expanding said mandrel mechanically  
13   with a cone-type device and then completing the  
14   expansion with said inflatable.  
15   29. The method of claim 1, comprising:  
16       expanding said tool into contact with the  
17   formation; and  
18       fracturing the formation by said expanding.  
19   30. The method of claim 6, comprising:  
20       expanding said tool into contact with the  
21   formation; and  
22       fracturing the formation by said expanding.  
23   31. The method of claim 18 comprising:  
24       expanding said tool into contact with the  
25   formation; and  
26       fracturing the formation by said expanding.  
27   32. The method of claim 18, comprising:  
28       providing at least two isolators disposed above  
29   and below said tool;  
30       providing at least one screen as said tool;  
31       expanding at least one of said isolators and  
32   said screen at least in part with said inflatable.

- 1     33. The method of claim 31, comprising:
- 2         fracturing the formation by said expanding of
- 3     said screen.



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Claims searched: 1-33

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## Patents Act 1977 Search Report under Section 17

### Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:  
UK CI (Ed.7): E1F (FJF, FMU, FLW, FJB, FLA)  
Int CI (Ed.7): E21B (43/08, 43/10, 43/14)  
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Category	Identity of document and relevant passage	Relevant to claims
A	GB 2343691 A (SHELL)	
A	GB 2336383 A (BAKER HUGHES)	
A	EP 0360597 A (HALLIBURTON)	
A, P	US 6263966 B (HAUT)	
A	US 5901789 (DONELLY)	

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